Report for 2001NY921G: Modeling phosphorus control best management practices on a watershed scale to improve surface drinking water quality

- Other Publications:
  - Gérard-Marchant, P.;T. S. Steenhuis; M. T Walter; V. T. Mehta; M. S. Johnson; and S. Lyon, 2002. Saturated Excess Runoff Modeling in Undulating and Mountainous Watersheds, Poster EGS02-A-00665, EGS XXVII General Assembly, Nice, France, April 2002.
  - Gérard-Marchant, P., 2002, The Soil Moisture Routing Model: A User Manual, Version 1.0, Soil and Water Laboratory, Biological and Environmental Engineering Dept., Cornell University, Ithaca, NY, USA.
- Articles in Refereed Scientific Journals:
  - Mehta, V.K., M.S. Johnson, P. Gérard-Marchant, M.T. Walter, and T.S. Steenhuis, 2001, Testing a Variable Source GIS-based Hydrology Model for Watersheds in the Northeastern US, the Soil Moisture Routing Model, Eos Trans. AGU, 82(47), Fall Meet. Suppl., Abstract H22I-05, 2001.
  - Walter, M. T.; T. S. Steenhuis; V. K. Mehta; D. Thongs; M. Zion; and E. Schneiderman, 2002, Refined Conceptualization of TOPMODEL for Shallow Subsurface Flows, Hydrological Processes, 16:2041-2046.
  - Walter, M. T.; V. K. Mehta; A. M. Marrone; J. Boll; T. S. Steenhuis; and M. F. Walter, 2002, A Simple Estimation of the Prevalence of Hortonian Flow in the New York City Watersheds, ASCE J. Hydrol. Engr. In press.
  - Mehta, V. K.; M. T. Walter; E. S. Brooks; T. S. Steenhuis; M. F. Walter; M. Johnson; J. Boll; and D. Thongs, 2002, Application of SMR to Modeling Watersheds in the Catskill Mountains. Env. Modeling and Assessment. In press.
  - Walter, M.T., V.K. Mehta, A.M. Marrone, J. Boll, T.S. Steenhuis and M.F. Walter, 2003, Simple Estimation of Prevalence of Hortonian Flow in New York City Watersheds, ASCE Journal Hydrological Engineering 8:214-218.
  - Johnson, M.S., W. F. Coon, V.K. Mehta, T.S. Steenhuis, E.S. Brooks, and J. Boll, 2003, Application of Two Hydrologic Models with Different Runoff Mechanisms to a Hillslope Dominated Watershed in the Northeastern US: A Comparison of HSPF and SMR, Journal of Hydrology 284:57-78.
  - Mehta, V., M.T. Walter, E.S. Brooks, T.S. Steenhuis, M.F. Walter, M. Johnson, J. Boll and D. Thongs, 2004, Application of SMR to Modeling Watersheds in the Catskill Mountains, Environmental Modeling and Assessment, In Press.
- Dissertations:
  - Johnson, M.S., 2001, Comparative Analysis of Two Watershed Hydrologic Models for a Central New York State Watershed: Hydrological Simulation Program - Fortran (HPSF) and the Soil Moisture Routing Model (SMR), MS Thesis, Cornell University, Ithaca, NY, USA.
  - Mehta, V.K., 2001, A Multi-Layered Soil Moisture Routing (SMR) Model Applied to Distributed Hydrological Modeling in the Catskills, MS Thesis, Cornell University, Ithaca, NY, USA.

Report Follows

Problem and Research Objectives:

Non-point sources –agriculture is no exception – are one of the largest contributions of phosphorus (P) to surface waters, where excess P typically results in eutrophication. The Environmental Protection Agency (EPA) generally requires filtration for surface water supplies. New York City (NYC) was granted an exemption from filtration for surface drinking water supplies provided that an acceptable watershed program plan and protective measures can be achieved, with significant emphasis on P control. A high priority has been placed on the development and implementation of effective best management practices (BMPs) for P control. However, no effective modeling tool is available to evaluate the potential impacts of BMPs on P transport in shallow, sloping soils such as occurring in the northeastern US.

The overall goal of this study is to develop and test a model that can predict, on the watershed scale, the transport of P from agricultural and forest lands on shallow sloping soils. This will be accomplished by: 1) performing laboratory and field experiments to understand P movement on shallow soils, 2) improving the spatially distributed Soil Moisture and Distribution model (SMDR) that includes P fate and routing routines, and 3) validating the model with data collected from Town Brook and other watersheds in the Catskills.

Methodology:

In order to understand P movement on shallow soils, we decided to put more emphasis on P loss from manure and fertilizers than was originally described in the proposal. A set of experiments will be carried out on sloping artificial runoff plots in the laboratory with a rainulator. Manure and/or fertilizers will be added on the top of the slope and the P concentration will be measured as a function of time and distance along the slope. Another set of experiments will be carried out in the field with milk house wastewater strips. The advantage of these strips is that daily P is added and, therefore, ideal to study the movement of P.

Phosphorus losses are highly dependent on the distance to streams. Therefore, P transport should be simulated with a model that conserves the spatial information. Spatially distributed models are ideal for this purpose. For this project, we will adapt the spatially distributed SMDR model by incorporating P generation and transport mechanisms (SMDR has been proven suitable for the hydrologic and geologic characteristics of the Northeast).

Validation will occur in two steps. First, the simple analytical relationships between soil P content and P concentration in surface and groundwater will be validated with simple laboratory experiments described above. Then, the SMDR model with the laboratory validated P routines will be tested on a watershed scale.

Principal Findings and Significance:

The project was funded in November 2001 and, consequently, the principal findings relate to the first half-year of the study.

The field laboratory studies with the milk house wastewater filter have been completed and showed that dissolved P can move over the same distance as a chloride tracer. The data need to be analyzed further and the results will be reported in next year's progress report. Laboratory studies have just begun.

During the first part of this calendar year, we prepared two publications concerning the validation of the previous version of SMDR (called Soil Moisture Routing Model or SMR). We also compared the model with the Hydrological Simulation Program – Fortran (HSPF). Discharges were simulated equally well with both models, but only SMR was able to accurately predict the spatial distribution of water and locations of runoff- generating zones in the watershed.

Most of the time was spent on stabilizing the new SMDR code. In this new code, infiltration and drainage are simulated more realistically. This was necessary in order to implement routines for P leaching in the soil. Evaporation calculation algorithms were also modified to take better into account the development stages of different vegetation covers. Additional routines were developed to simplify the generic use of the program and to streamline the importation of input maps or the creation of input look-up tables. A user manual, incorporating a fully commented code, has been released.

In addition, a simple model has been developed for the release of P from spread manure. This model links cumulative P load released to cumulative runoff, through a simple relationship requiring the knowledge of only two parameters: percentage of water-extractable P in the manure and the volume required to wash half the P out of the manure.

Finally, we have developed a routine that allows us to calculate the loss of land-applied manure. A fully distributed modeling of manure P leaching requires the knowledge of the actual location of the land-applied manure, as well as the quantities involved. Unfortunately, such data is not available. Therefore, a semi-distributed approach is followed. The watershed is divided in a number of geographical units. Each unit corresponds to the smallest area for which some information about manure application is available: for example, a farm, or a particular field in a farm, depending on the scale of the watershed. Each of these “manure application units” is then subdivided into elementary “spreading plots”. The size of each plot is defined as the area covered during a single manure spreading. For example, when manure application units are identified with fields, the plot size will correspond to the area covered by a single spreader, that is, a stripe of approximately 2000 m^2 (723’ x 33’ with a 4’overlap).